AD-A146 048 LASER COOLING AND TRAPPING OF NEUTRAL ATOMS(U) NATIONAL BUREAU OF STANDARDS GAITHERSBURG MD ELECTRICITY DIV W D PHILLIPS SEP 84 N00014-84-F-0020 1/1

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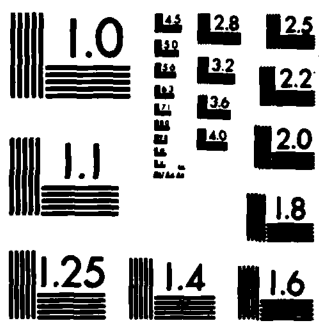

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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# REPORT DOCUMENTATION PAGE

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|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle) Laser Cooling and Trapping of Neutral Atoms | 5. TYPE OF REPORT & PERIOD COVERED Interim 1 Oct. 83 - 30 Sept. 84 |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) William D. Phillips | 8. CONTRACT OR GRANT NUMBER(s) N00014-84-F-0020 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS National Bureau of Standards Gaithersburg, MD 20899 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N NR 407-007 RR 001-03-03 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Physics Program Office Arlington, VA 22217 | 12. REPORT DATE September 1984 |
| | 13. NUMBER OF PAGES 3 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | 15. SECURITY CLASS. (of this report) Unclassified |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release; distribution unlimited



18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

atomic beams, atom traps, frequency standards, high resolution spectroscopy, laser cooling

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Using laser cooling techniques, we have produced a sample of stopped atoms with sufficiently large density and small velocity width to be useful for loading neutral atom traps.

Annual Summary Report

on

# LASER COOLING AND TRAPPING OF NEUTRAL ATOMS

by

William D. Phillips
National Bureau of Standards
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work supported by
Office of Naval Research
Contract No. N00014-84-F-0020
Task NR 407-007

Date of Report: September 1984

The highest resolution spectroscopy is ultimately limited by processes which relate to atomic velocities such as second order Doppler shift and transit time effects. Laser cooling of ions in traps promises to deal with these problems, but there is a great deal of interest in achieving the same benefits for neutral species. Unfortunately compared to ions, neutrals interact very weakly with external electromagnetic fields, so that it is much more difficult to trap them. Proposed traps using laser fields, electrostatic fields, or magnetic fields, have not yet been realized. Much of the difficulty centers on the very small energy depth of the neutral traps, and the difficulty in cooling atoms contained in such a trap, in contrast to the situation with ion traps. As a result, much of the interest now centers on the deceleration of a free atomic beam, either for direct use in high resolution spectroscopy or as a preparation for loading atoms into a trap.

Deceleration of an atomic beam is accomplished by directing a resonantly tuned laser beam opposite to a beam of neutral atoms. Repeated absorption of the laser light by the atoms, followed by spontaneous re-emission results in deceleration. Use of a magnetic field along with circular polarization of the laser avoids undesired optical pumping of the sodium used in the atomic beam. Causing the magnetic field to vary in space allows the changing Zeeman shift seen by the atoms to compensate the changing Doppler shift as the atoms slow down. In this way, resonance is maintained throughout the deceleration process.

A key problem with the technique described above is that while atoms can be brought to rest, this occurs in a region of strong magnetic field gradient, which makes utilization of the stopped atoms difficult. During the past contract period, we have solved this problem by allowing very slow atoms, created in the gradient field, to drift into a uniform field region after the decelerating laser beam is turned off. Once the atoms are well out of the gradient, the laser is pulsed on for a time sufficient to bring the atoms to rest.

The density of stopped atoms observed exceeds $10^5/cm^3$, with a velocity width of about 15 m/s. This density and spread should allow the loading of the atoms into a variety of magnetic or optical traps.

Articles published within the past contract period:

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H. J. Metcalf and W. D. Phillips, "Laser Cooling Atomic Beams," to be published in Comments on Atomic and Molecular Physics.

J. V. Prodan, W. D. Phillips, I. So, H. J. Metcalf, and J. Dalibard, "Stopping Atoms with Laser Light," to be published.

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